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Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
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If no title is shown please refer to the description.
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System and method for reproducing colors on a printing device

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[DESCRIPTION]

FIELD OF THE INVENTION

The present invention relates to methods and apparatuses for the reproduction of color documents; the invention especially concerns color management. The invention is particularly suitable for the reproduction of objects defined by a mixture of process inks and non-process inks.

BACKGROUND OF THE INVENTION

Today, more and more output systems are developed for the reproduction of color images. Several display and printing technologies are used such as CRT's, LCD's, conventional photography, electrophotography, thermal transfer, dye sublimation and ink jet systems' to name a few. In the rest of this document, these systems will be referred to as output devices.

All these systems can be described as multidimensional color devices with n colorants such as CMYK (cyan, magenta, yellow and black) inks of an ink jet system or RGB (Red, Green, Blue) in case of a display system. In this document it is assumed that the colorant values for printers range from 0% (no colorant laid down on paper) to 100% (maximum amount of colorant laid down on paper). For display systems, the values range from 0 to 255. In the rest of this document, mainly a printer will be used as an example of an output system, however, it is well known in the art of color management systems that all aspects of printers can be easily extended to those of a display systems.

With colorant space is meant an n-dimensional space with n the number of independent variables with which the output device can be addressed. In the case of an offset printing press the dimension of

the colorant space corresponds to the number of inks of the printer. As normally CMYK inks are used, the dimension of the colorant space is four. Colorant spaces are also referred to as device dependent spaces.

The colorant gamut is defined by all possible combinations of colorant values, ranging from 0% to 100% for printers and from 0 to 255 for display systems. If there are no colorant limitations, the colorant gamut is an n-dimensional cube.

With colorimetric space is meant a space that represents a number of quantities of an object that characterize its color. In most practical situations, colors will be represented in a 3-dimensional space such as the CIE XYZ space. However, also other characteristics can be used such as multi-spectral values based on filters that are not necessarily based on a linear transformation of the color matching functions. The values represented in a colorimetric space are referred to as colorimetric values. Colorimetric spaces are also referred to as device independent spaces.

A printer model is a mathematical relation that expresses colorimetric values in function of colorants for a given output system. The variables for the colorants are denoted as $c_1, c_2, \ldots, c_n$ with n the dimension of the colorant space. An n-ink process is completely characterized by its colorant gamut with a number of colorant limitations and the printer model. Because of this close relationship between an n-ink process and the printer model, the operations typically defined for a printer model are easily extended to an n-ink process.

The printer model is often based on a printer target. Such a target consists of a number of uniform color patches, defined in the colorant space of the printing device. In a next step the printer target is printed and measured, and based on the values of the patches in colorant space and the measured colorimetric values, the printer model is made. A printer target is normally characterized by

the sampling points along the different colorant axes. Based on the sampling points a regular grid can be constructed in colorant space of which a number of grid points are contained by the printer target. Hence a target can be said to be complete or incomplete. With inverting an n-ink process is meant that the corresponding printer model is inverted. The transformation of an n-ink process to colorimetric space on the other hand is equivalent to the transformation of the corresponding colorant domain to color space by making use of the printer model.

Based on a printer model, forward and inverse look up tables are constructed. These tables are also referred to as tables or color tables. A forward table transforms colorant values to colorimetric values whereas the inverse tables transforms colorimetric values to colorant values. Inverse tables are also called separation tables or color separation tables.

This invention is related to the rendering of page descriptions, consisting of multiple page elements such as text, different types of images and color gradations to name a few.

In most cases, the page elements are described in one or another color space, which may be either a device independent color space such as CIELAB, or a device dependent space such as RGB or CMYK. If the page has to be reproduced on a given output system, such as a printer or a display system, the color values have to be transformed to the proper colorant values of the output system at hand. This transformation is required as the color space of the page elements is in most cases different from the color space of the output system. In fact for most documents it is not known in advance on which output system it will be reproduced and the different page elements may be defined in different color spaces. Hence to reproduce these page elements, each element should be color managed by making use of the proper color transformations.

In a lot of cases, all page elements are defined in the same conventional color space. Depending on the application at hand, this will be a device dependent RGB, CMY or CMYK space. In home office environments, the RGB space corresponds to a monitor space and preferably the sRGB space is used. In a graphic arts environment, the CMYK values are typically standard Euro, SWOP or standard newspaper colorant values.

If the output system is known on which the document has to be reproduced, the color values have to be transformed unless the color space corresponding to the page elements corresponds to the color space of the output device. Such a transformation is in most cases done with color tables. A worldwide-accepted system to transform the colors is given by the ICC, the International Color Consortium. With this approach, each device is characterized to or from a device dependent color space. Such a transformation is described by tables, matrices and TRC's (Tone Reproduction Curves, i.e. one-dimensional look up tables) which are stored in a profile. In most cases profiles contain both forward and inverse color tables. Hence, if all page elements have the same color space, profiles can be used to perform the proper color management operations.

If on the other hand different page elements are defined by different but conventional color spaces, and these spaces can be described properly by conventional profiles, also the ICC approach can be applied. To support this functionality, different applications allow the embedding of profiles in images.

Nevertheless, there are a number of page elements that need special treatment. In offset printing for example, sometimes special inks are used that are significantly different from the conventional cyan, magenta, yellow and black inks, also referred to as the CMYK process colors. A typical example here are the so-called spot colors, that may be used either separately, in combination with other spot colors and/or in combination with the CMYK process colors.

Typically, spot colors are used if images are artificially created. The designer chooses one or multiple spot colors to render some image parts more exactly. In practice, a spot color is chosen out of a set containing hundreds of colors. As a result it is not practical to make color tables taking into account these special inks. Hence, the rendering of these colors is based on the colorimetric values of the 100 % patch. All in between colorant values are estimated by taking into account the colorimetric values of the paper and the 100 % patch.

Even more complicated is the situation in which multiple spot colors or spot colors and process colors are printed on top of each other. Here, many more ink combinations are possible and hence it is even impossible to print the most elementary combinations to be able to construct an accurate printer model.
In the case of spot colors, only the colorimetric values of the 100 % solids and the paper are known. Hence, if two spot colors are printed on top of each other with different colorant values, a model has to be used to predict the color of the overlap. However, the color of the overlap between two 100 % spot colors can not be accurately defined by the colorimetric values of the separate 100 % patches only.
It is therefore an object of the present invention to provide an apparatus and a method to make a color reproduction with improved color quality.
Another object is to provide an apparatus and a method to reproduce a color image on a receiving substrate with improved color quality.

SUMMARY OF THE INVENTION

The above-mentioned advantageous effects are realized by a method having the specific features set out in claim 1. Specific features for preferred embodiments of the invention are set out in the dependent claims.

Further advantages and embodiments of the present invention will become apparent from the following description.

DETAILED DESCRIPTION OF THE INVENTION

If in a page description an object is defined by a non-process ink, a technique is required to reproduce the object in a way that is in agreement with the expectations of the customer. In the graphic arts, such a non-process ink is called a spot color and is used in the design of an image to create special color effects.

If the images designed for an offset system need to be simulated or reproduced on another output system, profiles can be used to transfer the offset color values to a device independent color space whereas the profile corresponding to the output system will transfer these color values further on to the colorant values of the output system. As mentioned before, no color tables are available for spot colors and hence, the color values corresponding to colorant values of spot colors have to be predicted.

If the document is to be printed on an offset system, separations are made with which printing plates are etched. If only process colors are used, typically separations corresponding to the cyan, magenta, yellow and black ink are generated resulting in four printing plates. However, if also extra spot colors are to be printed, for every spot color an extra separation has to be made resulting in an extra printing plate.

Each printing plate is used to print one of the inks on paper. In printing, the amount of ink on paper is larger than the corresponding values sent to plate. This effect is known in the art as dot gain, and is considered as a typical characteristic for the printing environment characterized for example by the ink, paper and press combination. This means that if a spot color is printed, also for this spot color some dot gain has to be taken into account to predict the exact color. Hence, a technique is required that is able

to predict the dot gain as if the colors were printed in offset. This technique is expected to be defined by a number of parameters, but often only a dot gain value is specified for a given colorant value.

Spot color reproduction

The reproduction of a spot color can be considered as a model for a 1-ink process. As printer model the Neugebauer equations will be used as they are regarded as the basic model to predict color reproduction in offset printing. To apply dot gain, it is not always advantageous to apply the Yule-Nielsen correction as this correction is highly dependent on the measurement technique, specifically the filters used for the color measurements. Hence, a correction is needed that modifies the colorant value and based on the modified colorant value the Neugebauer model is used. Improved dot gain calculation over the Yule-Nielsen correction can be obtained based on real measurements and fitting a curve to predict the measurements in function of the colorant values. In case of a 1-dimensional process, the Neugebauer model corresponds to linear interpolation between the device independent color values of the paper and the 100 % solid of the spot color. A tristimulus space such as XYZ is a natural choice for this interpolation.

In a next step, the device independent color values have to be transformed to the device dependent color values of the output system. If color tables are used, as within the ICC framework, sometimes the colors are grayed out and a rendering intent has to be used that is not necessarily optimal for the rendering of spot colors. Hence, if the colorant values are represented with 8 bit data, separations for all 256 colorant values are calculated once or on the fly and used to transform the spot color values in the document to the color space of the output system.

Reproduction of two spot colors

In the case of two spot colors, only the colorimetric values are given for the 100 % patches (also referred to as the solids). Hence,

also in this case a model is required to predict the colorimetric values of all possible combinations of overlap. However, in general not enough information is available to use a printer model. Let us take the Neugebauer model for a 2-ink process as an example. This model is given as follows:

$$X = X_p(1-c_1)(1-c_2)k_0 + X_1c_1(1-c_2) + X_2(1-c_1)c_2 + X_{12}c_1c_2$$
$$Y = Y_p(1-c_1)(1-c_2)k_0 + Y_1c_1(1-c_2) + Y_2(1-c_1)c_2 + Y_{12}c_1c_2$$
$$Z = Z_p(1-c_1)(1-c_2)k_0 + Z_1c_1(1-c_2) + Z_2(1-c_1)c_2 + Z_{12}c_1c_2$$

with (Xp,Yp,Zp) the XYZ values of the paper
(X1,Y1,Z1) the XYZ values of the solid of the first spot color
(X2,Y2,Z2) the XYZ values of the solid of the second spot color
(X12,Y12,Z12) the XYZ values of the overlap of both spot colors
C_1 and C_2 the colorant value of the first and second spot color
(X,Y,Z) the XYZ values of the resulting color

As can be seen from this formula also the overlap of the two spot colors is needed.

To solve this issue, the transmission spectra of the solids and the reflectance curve of the paper can be used to predict the colorimetric values of the 200 % ink overlap. The simplest model that can be used are the spectral Neugebauer equations. However, several physical effects of light interactions at the ink surface, in the ink layers, between the ink layers and in the paper are neglected and have to be corrected. In the literature, several of these physical effects have been described and can be used successfully to get quite accurate color predictions.

Apart from a spectral modeling, a user also expects to be able to specify the dot gain of a printing process. Either this effect is modeled explicitly, what is in general quite difficult, or it is taken into account separately. In that case, dot gain can be modeled with curves that are defined experimentally.

Also in this case, the resulting colorimetric values have to be separated into the colorant values of an output device. This can be

done by making use of separation tables or dedicated 2-dimensional tables can be calculated in advance.

Reproduction of process colors and a spot color

Also in the case of mixing process colors and a spot color, a model is required to predict the colors of all possible overlaps. This model should be continuous related to the model used in the forward color separation tables if any combination of process colors and the spot color is present in the document. As these tables are regular grids, the forward regular grid can be easily extended with the spot color to obtain a 5-dimensional ink process. All the combinations of process inks in the forward table are maintained, and the solid spot color value is given. However, to be able to use interpolation schemes within color tables, at least all the corner points of the 5-dimensional colorant cube have to be specified. Hence, all combinations of 0 % and 100 % for the process colors and the 100 % of the spot color have to be provided. To predict these 16 combinations a printer model is needed. Also in this case a simple spectral Neugebauer process with additional dot gain modulation can be used or to have even a better prediction, more complex approaches modeling different physical processes should be taken. If a more accurate table is required, also combinations of the spot color between 0% and 100% with colorant values of the process colors can be determined with the printer model and filled out in the table. To keep the 5-dimensional forward table as small as possible, by preference only existing sampling points of the process colors are taken with a minimum number of extra values for the spot color.

In this way a non-regular grid is obtained from which an irregular localized model can be constructed as described in the patent EP 1 146 726 A1. Hence, a method is provided to build a forward model that is a trade-off between taking into account a minimum of extra patches and hence a model that is as small as possible and a more accurate model by filling out more colorant combinations resulting in a larger forward separation table.

For the inverse transformation from colorimetric space to colorant space of the output system, either the separation tables of the output system are used or inversions are made in advance or on the fly for certain colorant combinations.

If, however, only a limited number of combinations of the spot color and the process colors are present in the image, e.g. the spot color is only printed with cyan and magenta but not with yellow and black, then a smaller forward table can be constructed. In this way less colorant combinations have to be taken into account and continuity is guaranteed. If however no color gradations are present in the document that are a combination of the spot color and the process colors, only for those limited number of process colors with the spot color, the resulting color has to be predicted and the corresponding colorant values of the output system can be calculated in advance or on the fly.

Reproduction of process colors and several spot colors

The previous approach to predict the colorimetric values for the overlap between one spot color and process colors can be easily extended to several spot colors.

Having described in detail preferred embodiments of the current invention, it will now be apparent to those skilled in the art that numerous modifications can be made therein without departing from the scope of the invention as defined in the appending claims.

[CLAIMS]

1. A method for generating colorant values, in a system having at least one spot color, comprising the following steps:
   - establishing a printer model, encompassing said spot color
   - inverting said printer model
   - using said inverted printer model, for computing colorant values, representative for a required color.

■

[ABSTRACT]

SYSTEM AND METHOD FOR REPRODUCING COLORS ON A PRINTING DEVICE

A method and a system are described for the reproduction of colors on an output device. The system includes look up tables and/or separation functions.